Research Highlight

Arctic clouds are strongly tied to Arctic sea ice loss. To find the strength of those ties, a team led by scientists at Pacific Northwest National Laboratory tested a prominent climate model with observed data and found that it significantly underestimates liquid water content in the Arctic single-layer mixed-phase clouds, which affect how much solar energy transfers to the sea ice. They point out the areas of bias and recommend specific improvements to reduce those shortcomings. Their study is published in the Journal of Geophysical Research.

Led by Dr. Xiaohong Liu, an atmospheric scientist at PNNL, researchers tested the Community Atmospheric Model version 5 (CAM5), through two model frameworks. Both the Cloud-Associated Parameterizations Testbed (CAPT) and the Single-Column Modeling (SCM) testbed were used. CAPT and SCM are proven useful ways to understand climate model errors. The model results were compared and validated with the observational data obtained during the Department of Energy Atmospheric Radiation Measurement (ARM) Climate Research Facility's Indirect and Semi-Direct Aerosol Campaign (ISDAC) campaign conducted in April 2008 and the Mixed-Phase Arctic Cloud Experiment (M-PACE) campaign conducted in October 2004 near the ARM North Slope of Alaska site.

CAPT testing of CAM5 with both ISDAC and M-PACE observations clearly indicates the significant underestimation of cloud liquid water content in CAM5. As a result, CAM5 underestimates the surface downward longwave radiative fluxes by 20–40 W m-2. Introducing a new ice nucleation parameterization with one order of magnitude lower ice nuclei number concentration only slightly improves the model performance for low-level mixed-phase clouds by increasing cloud liquid water content through the reduction of the conversion rate from cloud liquid to cloud ice by the Wegener-Bergeron-Findeisen process.

The CAM5 single-column model testing shows that changing the instantaneous freezing temperature of rain to form snow from -5°C currently used in CAM5 to a more realistic value of -40°C causes a large increase in modeled cloud liquid water content through the slowing down of cloud liquid and rain-related processes (e.g., autoconversion of cloud liquid to rain). The underestimation of aerosol concentrations in CAM5 in the Arctic also plays an important role in the low bias of cloud liquid water in the single-layer mixed-phase clouds. In addition, numerical issues related to the coupling of model physics and time stepping in CAM5 are responsible for the model biases and will be explored in future studies.

Clouds over the Earth's poles get in the way of sunlight and the energy it carries to the surface. As a result, they can strongly affect Arctic climate change. To correctly predict future Arctic sea ice change, climate models must have a realistic simulation of Arctic cloud cover as well as cloud water amount. This study identifies areas for model improvements of cloud microphysics and aerosol parameterizations to reduce the bias in CAM5.

Reference(s)

Liu X, S Xie, J Boyle, SA Klein, X Shi, Z Wang, W Lin, SJ Ghan, M Earle, PS Liu, and A Zelenyuk. 2012. "Testing cloud microphysics parameterizations in NCAR CAM5 with ISDAC and M-PACE observations." Journal of Geophysical Research, 116, D00T11, doi:10.1029/2011JD015889.

Contributors

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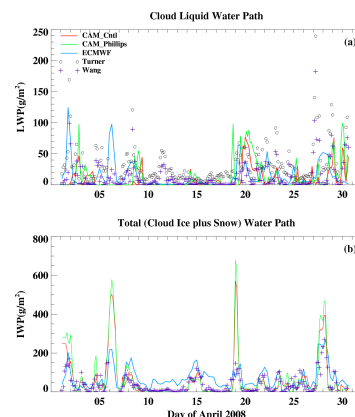
Time series of (a) liquid water path and (b) total ice water path (cloud ice plus snow) from the two CAM5 simulations (the control run and the run with the Phillips et al. (2008) ice nucleation parameterization) and the ECMWF reanalysis compared with remote sensing retrievals (Turner et al. 2007, Wang 2007) during the ISDAC period.

Working Group(s)
Cloud-Aerosol-Precipitation Interactions